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A new genus and species of the picture-winged moth from Borneo, with morphology and biology of the immature stages (Lepidoptera, Thyrididae)

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Abstract A new thyridid genus *Shafferiella* is described, based on *S. macarangae* n. sp. as the type species. Adult specimens of the new species were collected from the larvae on *Macaranga bancana* and *M. trachphylla* (Euphorbiaceae), also known as the ant plant, on Borneo Island, Malaysia. The immature stages are reported for the first time. Eggs are laid on the host leaf in a group, consisting of 83.3 eggs, on average. The egg is of the upright type, with distinct longitudinal ribs. The early instar larvae feed on the underside of the leaf of the host plant spinning a silken nest along leaf veins, and the mid- to last-instar larvae make cylindrical cases by cutting linearly and rolling up from the edge to the medial vein of the leaf, and live and feed inside the retreats. The larva has a globular sac inside the first abdominal segment, but the function of this organ remains unknown. Pupation takes place inside the last-instar larval retreat after reinforcing one side of the retreat with woven silk. Characteristics of the male genitalia and wing markings of the new genus are discussed, in comparison with those of two related thyridid genera, *Collinsa* and *Pharambara*. The larval morphology and behavior are also discussed in relation to those of other thyridids.

Key words biological traits, *Collinsa*, DNA barcoding, *Macaranga*, *Pharambara*, *Shafferiella* n. gen., Siculodinae.

Introduction

It is known that the fauna of the Thyrididae is rich in the Oriental region (Robinson *et al*., 1994), in comparison with that in the Holarctic region. This group is also abundant on Borneo Island, although several taxa are still unnamed (Sutton *et al*., 2015). The second and third authors found a thyridid species, reared on *Macaranga bancana* (Miq.) Müll. Arg. and *M. trachphylla* Airy Shaw, Euphorbiaceae, in Sarawak, Borneo Island, between 2009 and 2016 . Examination of the adults revealed that the species was apparently identical to *Pharambara* sp., belonging to the subfamily Siculodinae, in Robinson *et al*. (1994). This species was recently cited as *Collinsa* sp. 2 by Sutton *et al*. (2015), but it has not been described before.

The morphological characteristics of the immature stages of the thyridids in the Oriental region have been poorly investigated, although reports of their host plants are relatively numerous (Li, 1996 ; Robinson *et al*., 2001 ; Darling *et al*., 2001 ; Tominaga, 2003 , 2006 , 2009). Darling (2003) described morphological traits of the larvae of *Calindoea trifasciata* (Moore, 1877) of the Siculodinae, in Vietnam, focusing on a peculiar protuberance in the abdomen and its biological implications. This was the first detailed report on the larval morphology of siculodine species in this region, making an important contribution to knowledge about this subfamily.

We describe the new thyridid species mentioned above from Borneo, Malaysia, with DNA barcoding and report on the morphology and biology of the immature stages to further advance ecological research on this species, in comparison with *Ca. trifasciata*. In the course of the examination of this new species, it was found that this species had unique morphological traits and was distinct from the type species of the related genera, *Pharambara* Walker, 1866 and *Collinsa* Whalley, 1964. Thus, a new genus, ***Shafferiella*,** is proposed for this new species, with two other species that had been placed under *Collinsa*. We discuss the characteristics of the new genus in terms of the male genitalia and the wing markings, in comparison with those of *Pharambara* and *Collinsa*. We also discuss the characteristics of the morphology and behavioral traits in the larval stages of the new species.

Materials and methods

1. Morphology

Specimens of adults were taken by rearing larvae collected from *M. bancana* and *M. trachphylla* at Lambir, Sarawak, Borneo Island, Malaysia, in 2010 - 2016 . The eggs after hatching

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(exuviae) and the larvae were collected and preserved in 75 % ethanol in May, 2015 at the same place. A female pupa that was obtained in September, 2010, failed to emerge was used with ten pupal exuviae. The genitalia of the adults were examined with ordinal methods after treatment with 5 % KOH solution (Yoshiyasu *et al*., 2014) and were observed in a Petri dish with 75 % ethanol under a binocular microscope (M 205 C, Leica), using a digital camera system (IC 80 HD) for image photographing. The larvae preserved in 75 % ethanol were boiled in the 5 % KOH solution in a double boiler for ～5 min. Then, the sample was transferred to a Petri dish with water and cleaned, removing the internal organs. The materials were observed in another Petri dish with 75 % ethanol under a binocular microscope. Eggs (exuviae) in 75 % ethanol were air-dried and observed by scanning electron microscopy (JSM-5510LV, JEOL) after sputtering with gold.

The adult male specimen and its male genitalia slide of lectotype of *Dohertya roseopuncta* Warren, 1902, preserved in the Natural History Museum, United Kingdom, offered by David Lees, and the male genitalia of *Pharambara micacealis* Walker, 1865 (type species of *Pharambara*), at CSIRO, Australia, identified and offered by Marianne Horak and Ted Edwards, based on an Australian specimen, were used for comparison with those of the new species. Terminology for the genitalia followed Yoshiyasu *et al*. (2014) and that of the larval morphology and chaetotaxy followed Neunzig (1987), except for that of mandible in Hasenfuss (1980).

2. DNA extraction and PCR amplification

For DNA extraction, we used two dry moth adult specimens that were collected in their larval stages from *M. bancana* and thereafter reared in the laboratory until emergence in February and July, 2015 . DNA was extracted from an ethanol-preserved hindleg of each moth using the NucleoSpin Tissue kit (Macherey-Nagel, Düren, Germany) following the manufacturer's protocol. The nucleotide sequence of the insect barcoding region, the mitochondrial cytochrome oxidase subunit I (COI), was determined using polymerase chain reaction (PCR) as described in Kawakita *et al*. (2004).

3. Biology

To clarify the basic biological characteristics of this new thyridid species, we conducted a field investigation at the primary lowland mixed dipterocarp forest and at its surrounding areas in Lambir Hills National Park, Sarawak, Malaysia (4° 20 N, 113° 500 E, altitude 50 - 150 m). Details of the park as a study site were described in Yumoto and Nakashizuka (2005), and the climatic conditions there were described in Kumagai *et al*. (2009).

At least 17 species of *Macaranga* occur at the study site, and 12 of them are myrmecophytes (Shimizu-kaya *et al*., 2015). Most of them are pioneer tree species, occurring primarily at forest gaps, riverbanks, forest edges, and disturbed areas surrounding the primary forests (Itioka, 2005). Most of the individuals of the *Macaranga* myrmecophytic species have symbiotic relationships with their specific ant species, so-called "plant-ants", and the symbiotic relationships are highly mutualistic (Fiala *et al*., 1989, 1994); the myrmecophytes provide the plant-ants with nest spaces formed inside the hollow stems (Fiala & Maschwitz, 1992a) and with food resources, as food bodies produced on the surfaces of stipules or young leaves (Fiala & Maschwitz, 1992 b). In turn, the plant-ants protect their host plants from herbivores, especially phytophagous insects (Fiala *et al*., 1994; Itioka *et al*., 2000).

At the study site, we conducted field investigations more than 20 times intermittently at intervals of 1-6 months during the period from May, 2009 to March, 2016 . In each of the investigations, all herbivorous insects on the *Macaranga* plants were observed and counted, and sometimes collected for rearing in the laboratory. For this thyridid species, we recorded the numbers of immature individuals at different growth stages on each individual tree of the host plant species. We also recorded the physical patterns of herbivore damage by the moth larvae, and sometimes observed their feeding behaviors. Some larvae were collected and then brought to the laboratory for rearing. Each larva was placed in a transparent plastic case of 20 × 4 × 15 cm, fed with the leaf where the larva was found and reared to the adult stage.

Results

1. Description

The genus *Shafferiella* Yoshiyasu, **n. gen.**

Gender: Female.

Type species: *Shafferiella macarangae* Yoshiyasu, Shimizu-kaya & Itioka, **n. sp.**

Diagnosis. The new genus *Shafferiella* is distinct from its related genera, *Pharambara and Collinsa*, in having a short subapical white band in the forewing, a long intersegmental membrane between the 8th and 9th abdominal segments with a pair of hair pencils in the adult male, a longer and much slenderer valva in the male genitalia, a long ductus bursae, and a spinose signum on the corpus bursae in the female genitalia. Male and female. Head with vertex rather smooth; frons rounded. Chaetosema and ocellus absent. Antenna filiform, a little widened by suppressing, laterally. Labial palpus long, upturned: 1st segment short, 2nd segment long and curved, and 3rd segment short and narrow. Maxillary palpus small, proboscis long. Foreleg short and thick, with 1st tarsomere almost as long as tibia and longer than the others. Midleg long, with inner tibial spur twice as long as the outer one. Hindleg a little shorter than midleg, with both mid and apical inner tibial spurs almost twice as long as the outer ones. Wing shape and venation (Fig. 1D). Forewing with costa

weakly curved to rounded apex, termen evenly curved to tornus. Hindwing with costal margin curved proximally, apex broadly rounded, termen slightly excavated at vein M1 , then gradually curved to the tornus. Forewing with R, M, and CuA veins each emitted from discoidal cell; R4 and R5 approximated to each other at base; CuA2 emitting more proximal than R 1 from discoidal cell; discoidal cell open between vein M1 and M2; 2A anastomosed with 1A in the proximal portion. Hindwing with Sc+R1 reached wing apex, not touching Rs; base of M and CuA veins as in forewing; CuA2 emitted at proximal 1/2 of the posterior margin of discoidal cell; 3A short; discoidal cell short, distally open as in forewing. Wing markings (Fig. 1A). Forewing ochreous to pale brown; antemedial area with a faint band parallel with termen; medial area with a relatively distinct band from the costa to inner margin, almost parallel with termen; submarginal area near wing apex with a white short band or marking edged with blackish scales between veins R4 and M2; area beyond discoidal cell usually with small black dot(s) in cell M2 . Hindwing with a distinct medial band, extending to inner margin obliquely.Male genitalia and its related portions (Fig. 2). Tegumen relatively short, with dorsal surface undulated in lateral view, with anterior margin deeply invaginated in dorsal view. Fenestrulla developed between tegumen and gnathos laterally. Vinculum longer than the height of the tegumen. Uncus wide at base, being narrow and curved downwards to acute apex, with several short setae from near base to apex laterodorsally. Gnathos developed, extending anteriorly under tegumen, meeting midventrally to form a needle-like cochlear. Valva slender and elongate, with base wide but its distal 1/2 much narrower; costa weakly upcurved to near apex; transtilla shortly developed. Phallus relatively short, anterior portion a little curved downwards; vesica without cornutus; coecum penis undeveloped. Juxta complex in structure. Eighth abdominal segment relatively long and slender. Intersegmental membrane between 8th and 9th abdominal segments long, wholly covering external genitalia in normal condition and furnished with special scales and a pair of hair pencils ('coremata' *sensu* Choi, 2006) originating from near saccus (Fig. 10A). Female genitalia (Fig. 3). Ostium bursae narrow, simple. Ductus bursae long and narrow, with antrum near ostium bursae. Corpus bursae rather slender or sometimes large, elliptical, with a distinct spinose signum. Eighth tergum short. Apophysis anterioris and apophysis posterioris slender and short. Papilla analis thick and rounded, furnished with several setae laterally.

Etymology. The generic name is dedicated to the late Michel Shaffer (former curator of the Pyraloidea of the Natural History Museum, London) who made substantial contributions to knowledge on the thyridoid and pyraloid moths of Southeast Asia.

Species assigned to *Shafferiella* n. gen., other than *S. macarangae* n. sp.

Shafferiella pallida (Butler, 1879) (originally placed under the genus *Microsca*), **n. comb**.

Shafferiella hamifera (Moore, 1888) (originally placed under the genus *Pharambara*), **n. comb**.

Shafferiella macarangae Yoshiyasu, Shimizu-kaya & Itioka, **n. sp**.

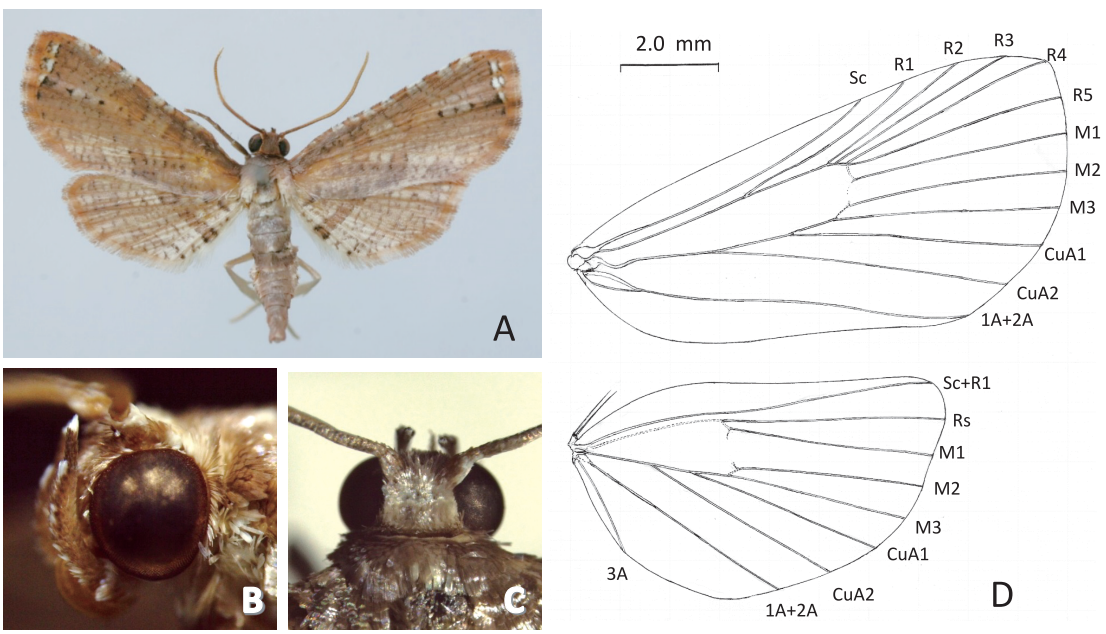

Fig. 1. Adults of *Shafferiella macarangae* n. sp. A. Male, holotype (forewing length: 7.8 mm); B. female, paratype, head, lateral view; C. *ditto*, dorsal view; D. wing venation, female.

（Newly proposed Japanese name: Ôbagi-madaramadoga）

Pharambara sp.: Robinson, Tuck and Shaffer, 1994 : 134 . pl. 23 , fig. 13.

Collinsa sp. 2: Sutton, Barlow and Whitaker, 2015: 11（pl. 3）.

Male and female（Figs 1A-C）. Forewing length: male 7.8-9.4 mm（*n*= 9）; female 8.5 -10.8 mm（*n*=10）. Head with vertex rather smooth, ochreous; area between antennae with long fulvous scales extending forwards; frons pale brown. Antenna

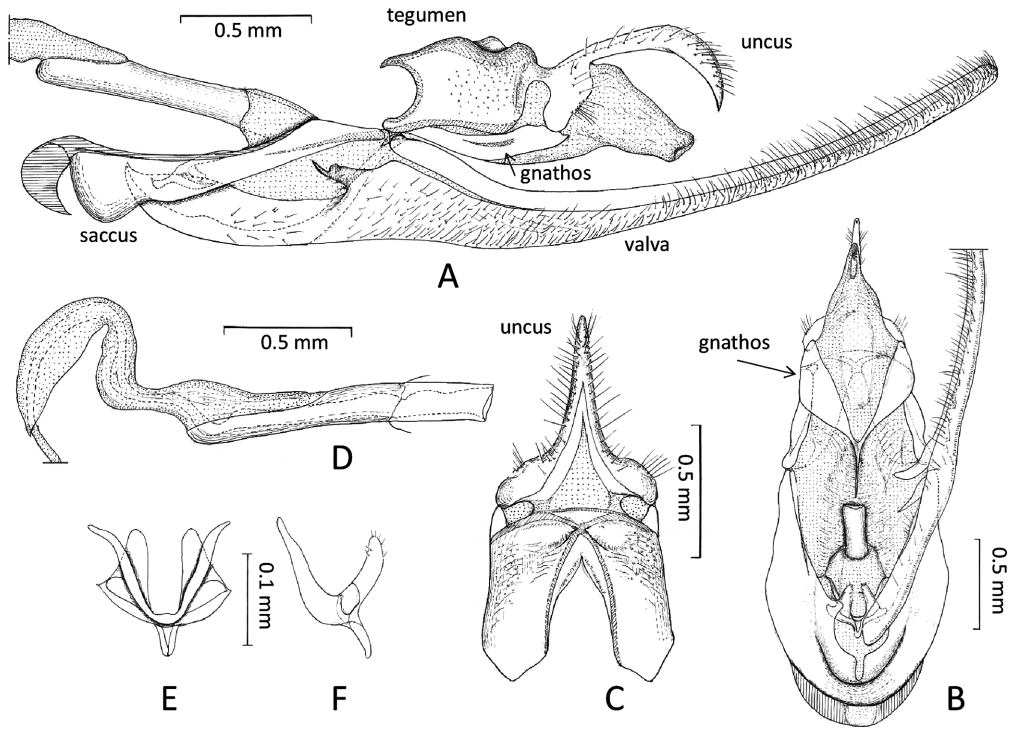

Fig. 2. Male genitalia of *S. macarangae* n. sp. A. Lateral view; B. ventral view, left valva removed; C. tegumen and uncus, dorsal view; D. phallus, lateral view; E. juxta, dorsal view; F. *ditto*, lateral view.

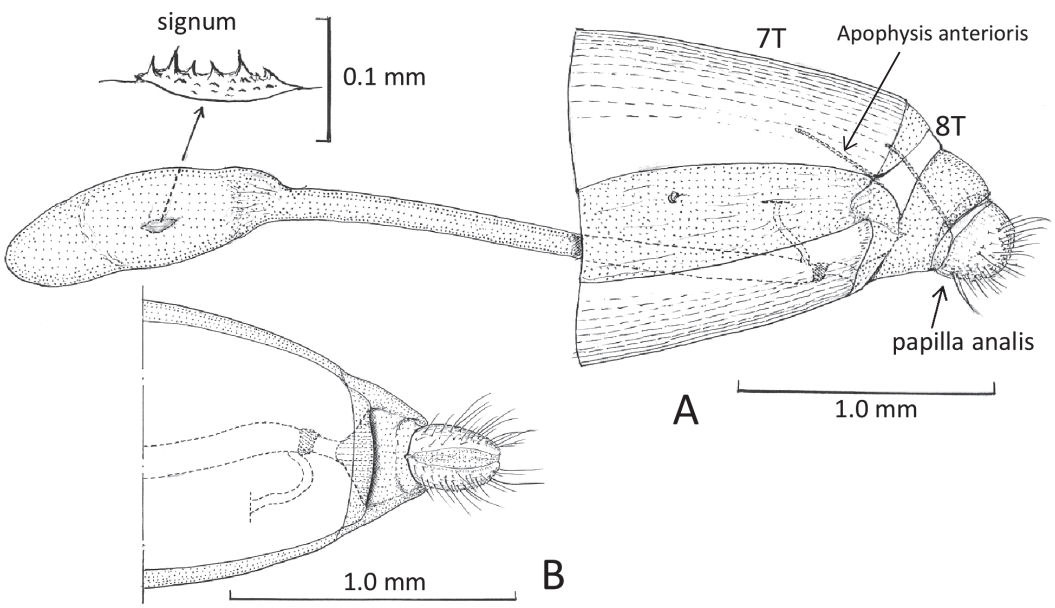

Fig. 3. Female genitalia of *S. macarangae* n. sp. A. Lateral view; B. ventral view. 7T & 8T: 7th tergum and 8th tergum of the abdominal segments.

filiform, slightly suppressed laterally in both sexes, fulvous dorsally, *ca* 1/2 as long as the forewing length. Labial palpus upturned along frons and extending to height of vertex, fulvous to fuscous, scattered with some whitish scales; 1st segment short and wide, with whitish apical scales; 2nd segment long and curved, scattered with some whitish scales anteriorly; 3rd segment narrow, fuscous except for whitish tip, *ca* 2/5 as long as the 2nd one. Maxillary palpus fulvous. Thorax above ochreous and slightly glossy anteriorly, below whitish. Foreleg chocolate brown anteriorly, being paler posteriorly, with a whitish apical marking at each tarsomere. Midleg long, same as in foreleg in color. Hindleg whitish to fulvous, with tibia and tarsus each *ca* 7/10 as long as those of midleg. Abdomen above pale fulvous, with a little darker band on 3rd segment; below whitish. Wing markings (Fig. 1A). Forewing with ground color ochreous to pale pastel brown, with many faint darker short lines between veins; costal area with seven whitish markings from base to near apex; antemedial area with a broad and darker band; medial area with a darker band, almost parallel with termen; submarginal to marginal area near apex with a white and crescent-shaped band edged with black on both sides from vein R4 to vein M2, which is interrupted by veins; 3-5 small and black dots present in cell M2 beyond discoidal cell; cilia light ochreous, with darker scales at terminal end of each vein. Hindwing with ground color as in forewing, with a characteristic medial dark brown broad band from costa to inner margin obliquely, and a faint submarginal band a little clearly recognized at tornal area; cilia as in forewing. Male genitalia (Figs 2, 10A). Tegumen relatively short, with dorsal surface undulated in lateral view, with anterior margin invaginated in V-shape in dorsal view and roundly excavated in lateral view. Saccus rounded, with an anterior process, being origin of a tuft of long scales (hair pencil). Uncus with distal 3/4 narrow in dorsal view and falcate and curved downward to acute apex in lateral view, with several short setae from near base to apex laterodorsally. Gnathos with its midventral cochlear suppressed laterally, much narrow and acute at apex. Valva as in generic description in shape; transtilla short; sacculus wide at base; inner surface with a short process orientating anteriorly at the proximal portion and distal slender half furnished with many short and curved setae. Phallus relatively short, anterior portion a little curved downwards. Juxta consisting of two pairs of processes, of which dorsal one is narrow and ventral one is broad and flat. Female genitalia (Figs 3, 7B-D). Ostium bursae narrow, covered ventrally with a deltoid-shaped postvaginal flap in 8th abdominal segment. Ductus bursae narrow, with antrum rectangular near ostium bursae. Corpus bursae long ellipsoid; signum small and narrow, with some minute spines innerly (Fig. 3A). Eighth tergum short; apophysis anterioris short, almost 1/3 as long as 7th tergum, Apophysis posterioris a little longer than its anterioris. Papilla analis thick and rounded, furnished with several short to long curved setae laterally. Egg (Figs 8A-E). Length 0.52 mm, diameter 0.25 mm (n= 10). Rather long, cylindrical, with anterior end (top) a little narrowed and rounded, and posterior end (bottom) flat. Whitish in color, becoming dark brown before hatching. Micropile on anterior end surrounding by nearly

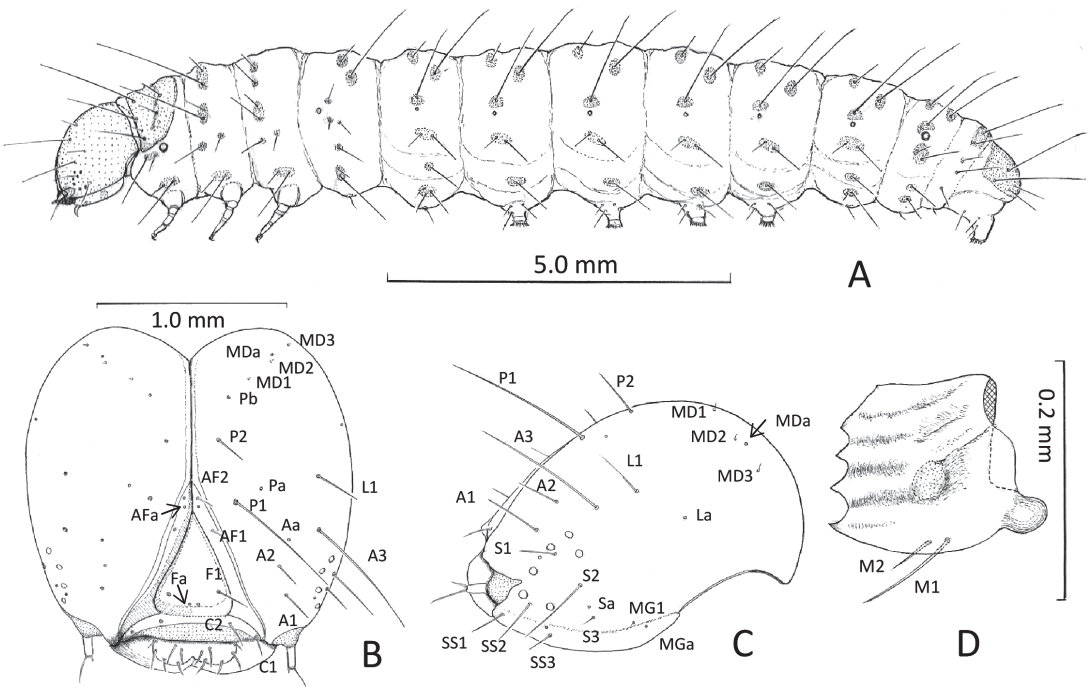

Fig. 4. Last instar larva of *S. macarangae* n. sp. A. Lateral view; B. head, frontal view; C. *ditto*, lateral view; D. right mandible, inner view.

pentagonal chorion. Lateral side with 14 or 15 distinct longitudinal ribs at even intervals. Area between the ribs with regularly arranged depressions, looking like plant cells (Fig. 8D). Mature larva (Figs 4-5, 7A-D, 9E). Body length 15-18 mm, head width 1.6-1.7 mm (*n*=4) in 75 % ethanol preservation. Head evenly pale orange; labrum pale brown. Stemma blackish, small, six in number. Antenna long. Mandible (Fig. 4D) light brown, almost quadrate, with four teeth; inner teeth undeveloped, with medial portion weakly membranous circularly. Thorax and abdomen pale yellow, semi-translucent and a little shiny as in other thyridid larvae when they are alive. Prothorax (T1) with its shield pale orange, swollen posteriorly; spiracle just ventrad of shield, large and circular. Meso- and metathoracies short. Thoracic legs pale yellow (Fig. 7A), each with light brown claw. First abdominal segment with a globular invaginate sac between L1+L2 and L3 setal area (Figs 7A-B), and a pinaculum of L1 +L2 nearer to spiracle, and L 3 shifted more dorsad. Spiracle on 1st abdominal segment small circular, and shifted anteriorly; those on 2nd to 7th abdominal segments smaller than that of 1st abdominal segment; spiracle on 8th abdominal segment almost as large as that of prothorax. Prolegs on 3rd to 6th abdominal segments with crochets triordinal, arranged in irregular triserial circles, *ca*. 50 in number of which the longer crockets are 12 - 14 in number, shifted inside (Fig. 7C). Anal shield developed, pale brown. Anal proleg with irregular triordinal crochets, *ca* 20 in number, in a semicircular arrangement. Chaetotaxy (Figs 4B-D, 5): head with P1 and A3 long and other setae relatively short; A1 short, anterior to a little shorter A2; A3 posterolateral to A2; P1 as long as A3; P2 dorsal to P1, short; Pb present behind P2; L1 short, behind long A3; S3 short, ventrad of longer S2; SS2 longer than SS1, near to stemma 5 ; MD1 , MD2 and MD3 almost on a oblique line; G1 short, anterior to Ga. Mandible with M1 almost twice as long as M2. Prothorax with XD1 and XD2 long, others short or moderate in length; SD2 2/3 the length of dorsal XD2; D2 short, just ventrad of D1 ; L1 long, L2 about 1/4 the length of L1 in the same pinaculum; SV1 long, SV2 short, in the same pinaculum. Mesothorax with D1 and D2 in a same pinaculum, D1 short and D2 very long; SD2 and SD1 in a same pinaculum; L1 longer than L2; SV1 long, lateral to short SV2. Metathorax with D1 and D2 short on each separate pinaculum; SD1 and L1 shorter than those of mesothorax. Abdomen with pinacula slightly swollen, almost concolorous with body. On 1st abdominal segment, D1 short; D2 much long, postero-ventrad of D1; SD1 short; each L seta shifted more dorsally than in the following segments, nearer to the spiracle; SV1 long, SV2 short; V1 short. On 2nd to 7th abdominal segments, D1 short; D2 very long; longer than the width of each segment; SD1 very long, just dorsad of the

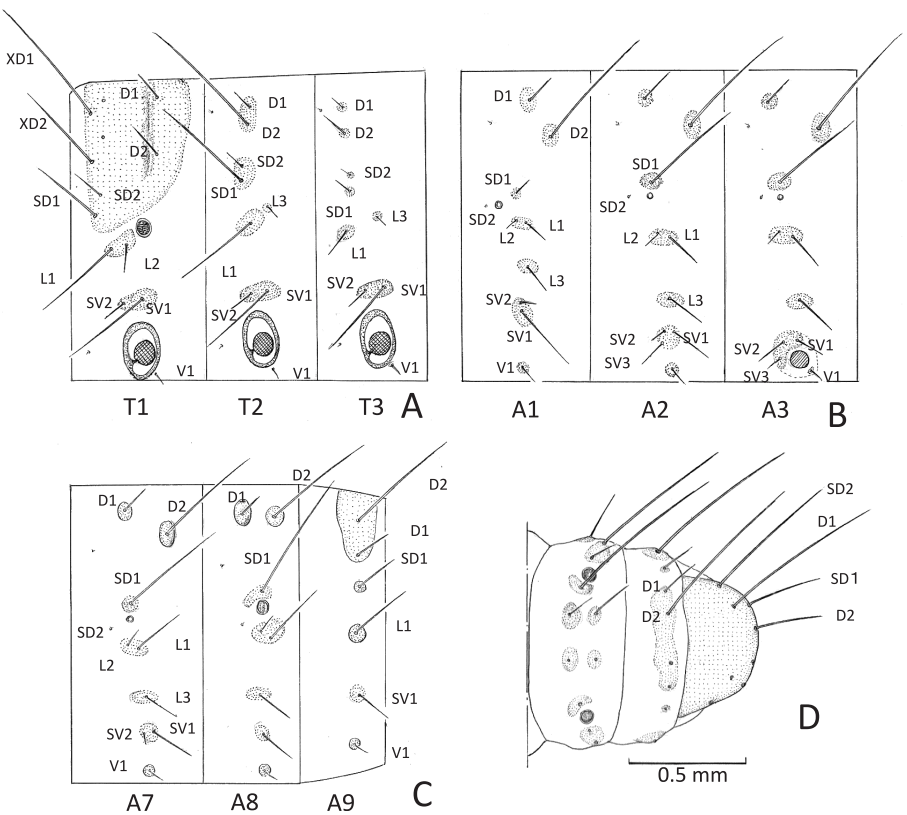

Fig. 5. Larval chaetotaxy of *S. macarangae* n. sp. A. Pro- to metathoracies; B. 1st to 3rd abdominal segments; C. 7th to 9th abdominal segments; D. 8th to 10th abdominal segments, dorsal view.

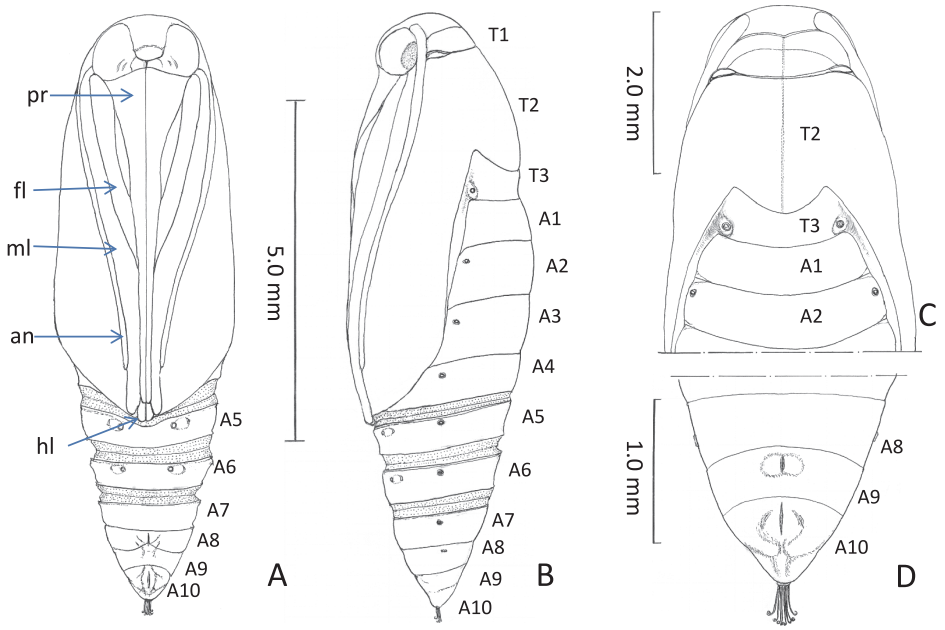

Fig. 6. Pupa of *S. macarangae* n. sp. A. Female, ventral view; B. *ditto*, lateral view; C. *ditto*, anterior portion, dorsal view; D. male, posterior portion, ventral view. an: antenna; fl: foreleg; hl: hindleg; ml: midleg; pr: proboscis.

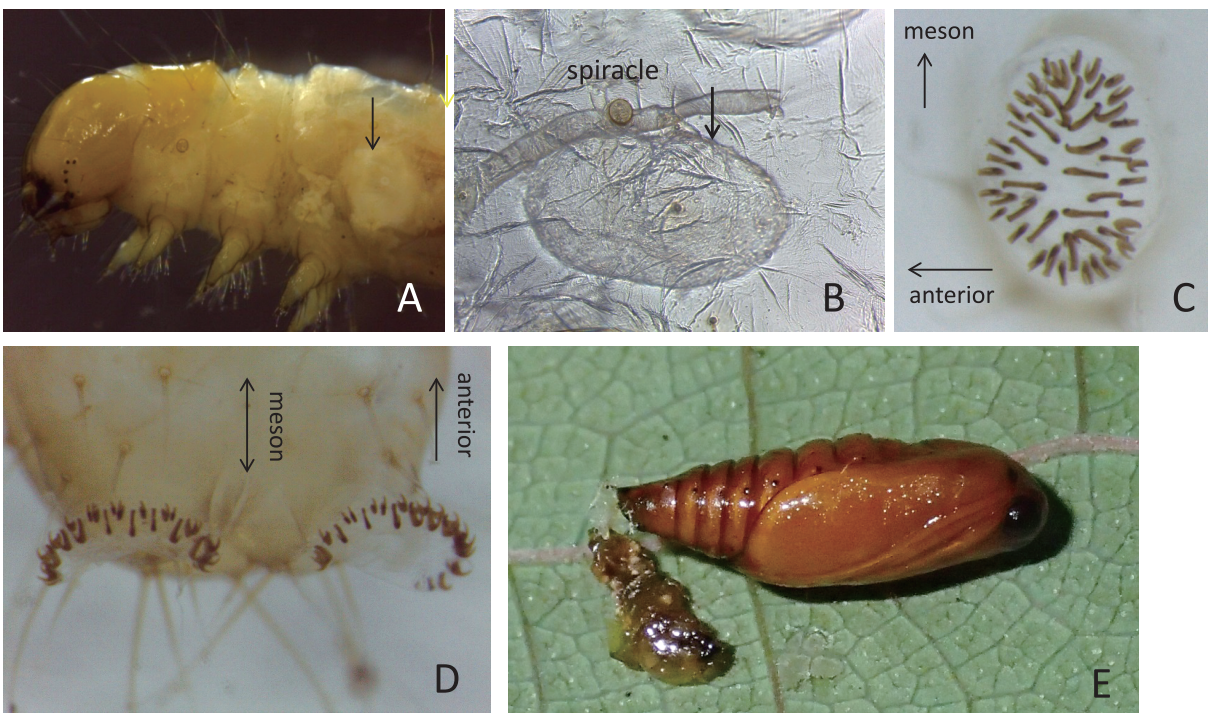

Fig. 7. Larva and pupa of *S. macarangae* n. sp. A. Mature larva, head to 1st abdominal segment (A1); B. an internal sack on A1; C. crochets of 3rd abdominal proleg; D. anal proleg with crochets, ventral view; E. a pupa pulled out of retreat, lateral view. Arrows in A & B indicate internal sac in A1.

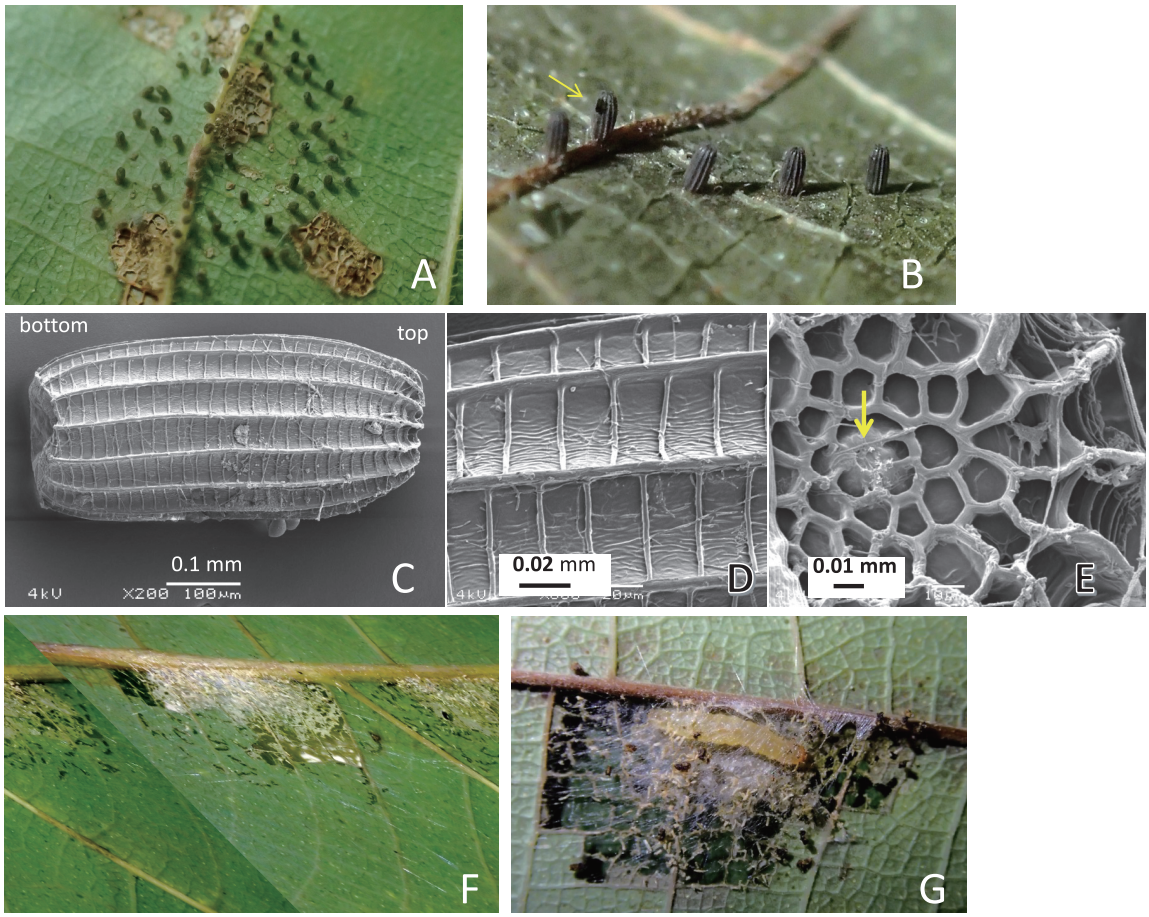

Fig. 8. Egg and early instar larva of *S. macarangae* n. sp. A. Eggs underside of a leaf of *Macaranga bancana*; B. *ditto*, enlarged (larval exit hole indicated by the arrow); C. egg, lateral view; D. *ditto*, lateral sculpture; E. *ditto*, micropyle surrounded by chorion indicated by an arrow; F. larval silken nests along leaf vein underside of a leaf made by early instar larvae; G. 1st instar larva inside nest.

spiracle; SD2 minute anterior to the spiracle; L1 and L2 on the same pinaculum, L3 as long as L1, remote from L1+ L2; SV1 as long as L3, SV2 and SV3 short. On 8th abdominal segment, D2 long, lateral to short D1 ; SD1 much longer, just dorsad of the large spiracle; L1 and L2 nearer to the spiracle; L3 and SV1 a little shorter than L1. Number of SV group of setae in 1st to 8th abdominal segments: 2, 3, 3, 3, 3, 3, 2 and 1, respectively. Ninth abdominal segment with D1 short, ventrad of long D2 in the same pinaculum which is fused with a pinaculum of the opposite side at the middorsal line; D1, D2, SDl, L1, SV1 and V1 situated on a vertical line. Tenth abdominal segment with anal shield (Fig. 5D) with two long D setae antero-lateral to two short SD ones. Pupa (Figs 6, 7E). Length 8.5-10.5 mm, width 2.5-2.8 mm (based on a female pupa and 10 pupal exuviae, n = 11). Short and stout, light brown. Head with setae reduced; labrum clearly marked; vertex rounded. Labial palpus not apparent. Proboscis of maxilla long, appearing along the midventral line to near the apex of the wing. Antenna extending a little before wing apex. Midleg reaching to anterior margin of 5th abdominal segment. Hindleg with apex shortly appeared behind proboscis. Prothorax with a spiracle clearly marked at the posterolateral corner. Scars of 5th and 6th abdominal prolegs in larval stage rather distinct. Spiracles on mesothorax and 1st abdominal segment large, and those on 2nd to 7th abdominal segments small, that on 8th abdominal segment narrower than those of preceding segments. Cremasterial hook consisted of four pairs of thick setae, with each apex curled.

Holotype. Male, Lambir Hills National Park, Miri, Sarawak, Malaysia, coll. 7. Feb. 2015 (larva). em. 24. Feb. 2015, Usun Shimizu-kaya leg., rearing No. SKU 15 - 0009 , reared from *Macaranga bancana*. Paratypes: 9 ♂ 10 ♀ . Same locality and same collector as follows: 1 ♂ , coll. 18 . Sept. 2010 (larva), em. 8. Oct. 2010, from *M. bancana*; 1 ♀ , coll. 7. July 2015, em. July, 2015 from *M. bancana*; 4 ♂ 4 ♀ , coll. 7 and 9. Feb. 2015 (larva), em. 18-25. Feb. 2015, from *M. bancana*; 4♂ 5♀ , coll. 16. Jan. 2016 (larva), em. 26-30. Jan. 2016, from *M.*

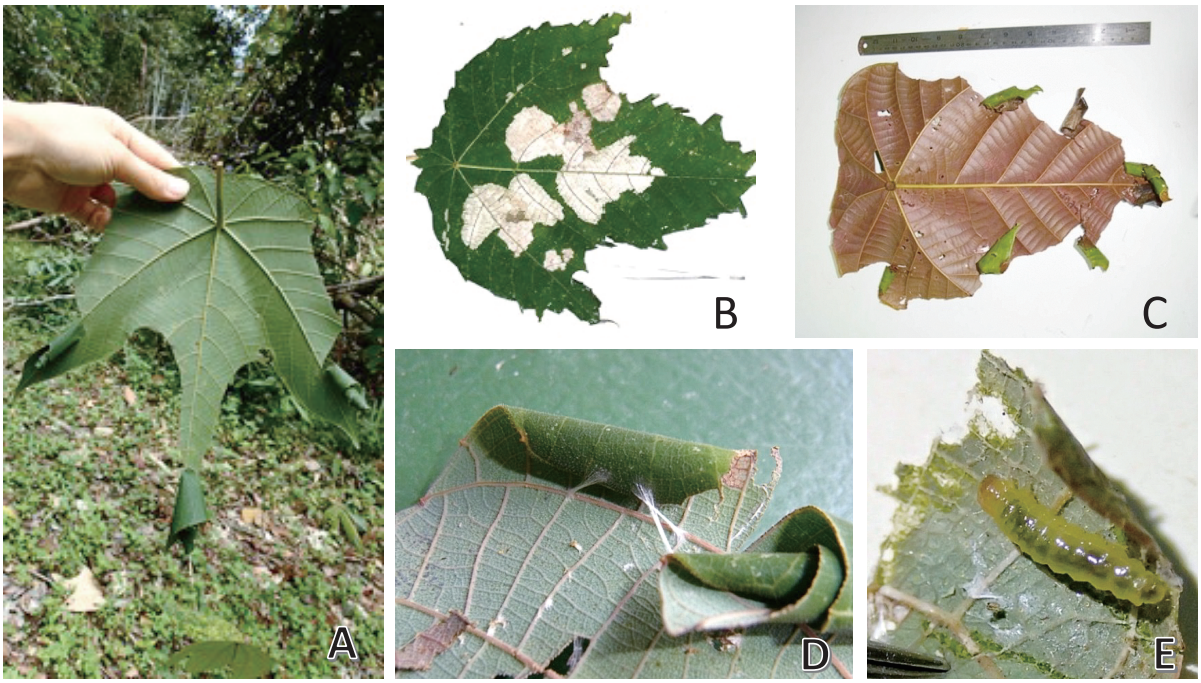

Fig. 9. Feeding habit of larvae of *S. macarangae* n. sp. A. Larval retreats (second leaf rolls) of late instar larvae on *Macaranga bancana*; B. feeding traces (whitish portions) by early instar larvae and small retreats (first leaf rolls) along leaf margin on *M. trachyphylla*; C. larval retreats (second leaf rolls) on *M. umbrosa*; D. *ditto*, on *M. trachyphylla*; E. a mature larva inside a retreat.

trachphylla. Type-depository. The Forest Department Sarawak, Malaysia (with paratypes 2♂ 2♀). Other paratypes are preserved in The Kyoto University Museum (3♂ 3♀) (including 1♂ 1♀ for DNA extraction), Kyoto Prefectural University (1♂ 1♀), Osaka Prefecture University (1♂ 2♀), the Natural History Museum, London (1♂ 1♀), and CSIRO, Canberra (1♂ 1♀).

Etymology. The specific epithet comes from the generic name of the host plant, *Macaranga*.

Host plant. (mostly) *M. bancana* (Miq.) Müll. Arg., *M. trachyphylla* Airy Shaw, and (rarely) *M. umbrosa* S. J. Davies (Euphorbiaceae).

Distribution. Malaysia (Sarawak, Sabah, Kalimantan Tengah, West Malaysia), Singapore. Lowland to lower montane up to 1,200 m (Robinson *et al*., 1994: Sutton *et al*., 2015).

2. DNA barcoding

The sequence obtained was submitted to the DNA Databank of Japan (DDBJ) database under accession number LC163923 . Using BLAST, we searched for sequences with high similarity to the sequence obtained for the new species. Although few Thyrididae sequences are available in the database, the sequences with the highest similarity were those of *Collinsa acutalis* (Walker, 1866) (accession number GU695607; identity score, 92 %).

3. Biology in the immature stages

In total, we found eggs on one *M. bancana* and one *M. trachyphylla* trees. On each tree, eggs were laid in a group, being spaced out at almost even intervals, on the abaxial side of a mature leaf (Figs 8 A-B). Five egg groups were found in total: two groups were found from two different mature leaves on the *M. bancana* tree, and three from a same mature leaf, at intervals of 5 - 15 cm from each other, on the *M. trachyphylla* tree. The number of eggs in a group ranged from 62 to 113 (mean = 83.3, SE = 9.5 , n = 4), except for one group consisting of five eggshells on *M. trachyphylla*. We did not observe hatching behavior. In both the field and the laboratory, early instar larvae were observed to feed on leaf tissues inside silken nests that they wove at the lateral sides of leaf veins on the abaxial leaf surfaces (Figs 8F-G). Although we were not able to check whether any ecdysis occurred, it is possible that the larvae molt inside the silken nests. Each larva moved to the leaf edge, rolled up the leaf, cutting linearly from the edge to the medial vein of the leaf, and eventually formed a cylindrical leaf roll (Figs 9A-C), when it grew up to ～ 8 mm in body length, and probably with the procession of growth stage (the correct growth stage at the movement remains unclear). The end of leaf roll at the basal leaf side was often somewhat flatly squashed and occluded by silken webs. The leaf roll was 9 - 15 mm in length and ～5 mm in diameter, or in width if the end was flatly squashed, at the basal end. The larvae at this stage were confirmed to feed on leaves

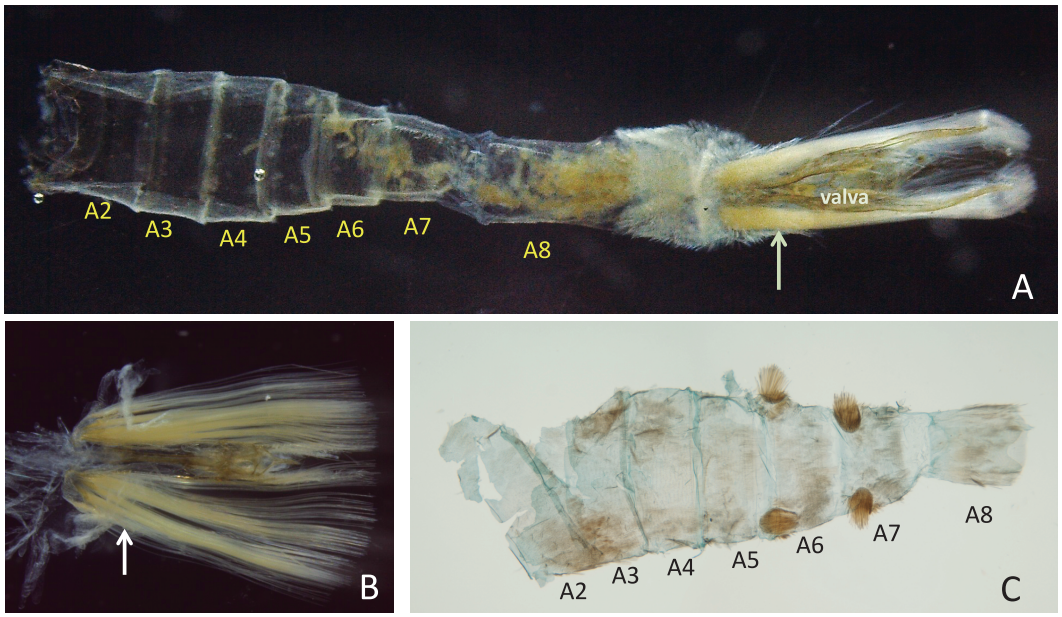

Fig. 10. Male abdomen of *S. macarangae* n. sp. and *Pharambara micacealis*. A. *S. macarangae*, ventral view, hair pencil (indicated by the arrow) between A8 and A9, covering valvae laterally; B. *ditto*, hair pencil, intersegmental membrane between A8 and A9 removed, dorsal view; C. *P. micacealis* (from Australia), ventral view (note a pair of scale tufts on A6 and A7). A2-A8: 2nd to 8th abdominal segments.

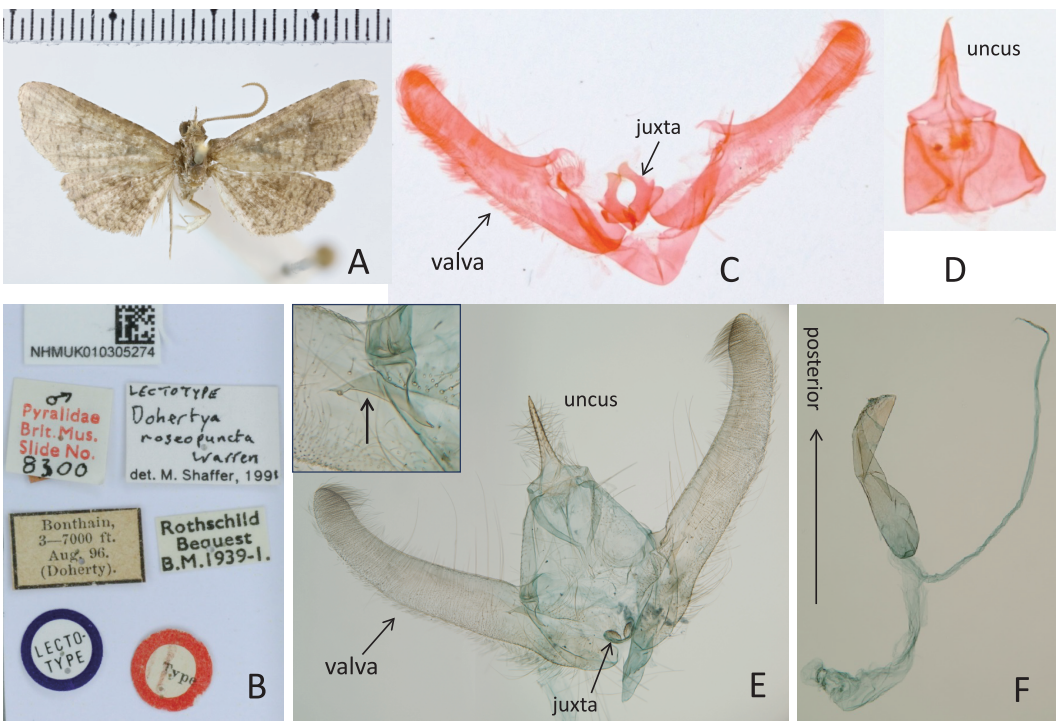

Fig. 11. *Collinsa roseopuncta* and *Pharambara micacealis*. A. *Co. roseopuncta*, lectotype, male (NHM, London, provided by D. Lees); B. *ditto*, labels of the lectotype; C. *ditto*, male genitalia (part), ventral view (NHM, #8300); D. *ditto*, tegumen and uncus, ventral view; E. *P. micacealis* (CSIRO, Australia, provided by M. Horak and T. Edwards), male genitalia, ventral view, with base of left valva enlarged in the left upper square (a process indicated by the arrow); F. *ditto*, phallus.

inside the leaf rolls, both in the field and in the laboratory. We observed some herbivory traces on the tissues of rolled leaves for at least 30 unoccupied leaf rolls, which had been abandoned by the larvae, in the field. After further growth in body size through one or more larval ecdyses, it moved out of the leaf roll to a younger leaf, mostly to the first or second leaf upper than the leaf where it hatched. There, it built the 'second' leaf roll, which was obviously larger than the previous one ('first' leaf). Additionally, the method of building differed between the two leaf rolls. The second leaf roll was divided into two parts: an outer cover part with the shape of a truncated cone at the basal leaf side, and an inner tightly rolled part with the shape of a cylinder at the leaf extremity side (Fig. 9 A). The basal end of the outer cover was often somewhat flatly squashed and occluded by silken webs at the edge of the rolled outer cover from inside the roll (Fig. 9D). Because most of leaves were cernuous, and because the cone and cylinder axes were usually arranged in the vertical direction on such leaves, the upper part of most of the second leaf rolls was surrounded by the outer cover. The roughly measured lengths and the diameters were 30-50 mm and *ca*. 10 mm, respectively. No feeding behavior outside the second leaf roll was observed, nor confirmed with any herbivory traces, in the laboratory rearing of 191 larvae at the growth stage. On average, they pupated *ca*. 10 days after the formation of the first leaf roll under laboratory conditions. Each pupa was fixed to the silken web woven for the upper end of the second leaf roll, and every newly emerging adult got out of the roll through the other side. Although all of the trees that were infested with any immature individual of this thyridid species were of the myrmecophytic species, the number of ants attending to the host plant surface was clearly much lower than usual on most of the uninfested trees of the same species and no physical contact was observed between them in the field. On such trees, the local density of leaf rolls, consisting of all occupied and unoccupied first and second ones, reached 87 per tree and 50 per leaf; the mean number per tree for the trees with at least one leaf rolls and the mean number per leaf for the leaves with at least one leaf roll were 35.9 (SE = 7.7, n = 13) and 7.5 (SE = 1.0, n = 62), respectively.

Discussion

1. Morphological characteristics of *Shafferiella* n. gen.

Robinson *et al*. (1994) recognized this new species for the first time and placed it under the genus *Pharambara*. The genus *Pharambara* contains seven named species in the Oriental and Australian regions (Robinson *et al*., 1994 ; Shaffer & Nielsen, 1996), with the type species, *P. micacealis* Walker, 1865 (type locality: Mysol Is., Indonesia). The male genitalia of *P. micacealis* bear some resemblance to those of the new species in having a basal process on inner surface of the valva (Fig. 11E), the phallus is rather short without a coecum penis or cornutus, and with a narrow uncus (Fig. 11F). However, the former is significantly different from the new species in the following respects. The tegumen is not invaginated anteriorly, the valva is not as long and moderate in width, and the juxta is smaller and simpler (Fig. 11E). *Pharambara micacealis* is also characteristic in having a pair of scale tufts on both the 6th and 7th abdominal segments (Fig. 10C), which are absent in the new species. Additionally, the wing markings and shape of *P. micacealis* are distinct from those of *S. macarangae* n. sp. as follows: the forewing is more acute at the apex and lacking a white marking near the apex and the hindwing termen is strongly excavated behind the apex. Some of these fundamental differences may be the reasons that Sutton *et al*. (2015) transferred "*Pharambara* sp." in Robinson *et al*. (1994) to the genus *Collinsa*. The genus *Collinsa* was established based on *D. roseopuncta* Warren, 1902 which is the type specimen of the genus *Dohertya* Warren, 1902 from Sulawesi, Indonesia (Figs 11A-D, Lectotype, NHM, London). Whalley (1964) proposed the genus *Collinsa* as a replacement name for *Dohertya* preoccupied by Hampson (1894). The male genitalia of the new species differed from *Co. roseopuncta* in some respects. For example, the tegumen is not invaginated anteriorly along the middorsal line and the valva is moderate in length and not slender (Figs 11C-D). The wing markings of the new species also differ from *Co. roseopuncta* (Fig. 11A) in having the apical white band in the forewing and a rather distinct medial band in the hindwing (Fig. 1A), although both species are similar in wing shape. We could not confirm the male hair pencil of the latter species. The male genitalia characteristics of the new species are much closer to those of "*Rhodoneura hamifera* (Moore, 1888)" and "*R. pallida* (Butler, 1879)" described in Choi (2006) in having a similar tegumen and uncus, a much long and slender valva with a basal process, and the hair tuft (hair pencil) in the intersegmental membrane between the 8th and 9th abdominal segments in the male, together with similar wing markings. These two species were suggested to be transferred to *Collinsa* in Choi (2006), and were placed under the genus *Collinsa* in Owada & Wan (2010), without comment on the generic changes. Considering these morphological similarities, as in the description of the new genus, it seems appropriate to treat these two species as members of *Shafferiella* n. gen. Sutton *et al*. (2015) provided adult images of 33 species, including 22 unnamed or undetermined species, placed under *Collinsa* from Southeast Asia, of which some species could be likely transferred to this new genus with future study, especially *Co. acutalis*, given the close affinity of the new species as identified by BLAST searching.

2. Larval morphology and behavior

Darling *et al*. (2001) reported a pair of protuberances on the 1st abdominal segment of the larva of *Calindoea trifascialis* and the organ played a role in producing a cyanogenic secretion from the inner sac. This organ was eversible and was suggested to serve a function as a source of allomones for natural enemies, such as ants, and the same organ was also confirmed to be present in

another Australian thyridid species (Darling, 2003). To our knowledge, this abdominal organ is unique to this family, although similar scent organ is known in the Yponomeutidae as a cervical gland in the prothorax, and it supposed to emit trail pheromone (Povel and Beckers, 1982). In the new species, we found an inner sac at the same position on the first abdominal segment (Figs 7A-B), but the outer protuberance from the sac seen in *Ca. trifascialis* was undeveloped. Despite this morphological difference of the organ, it seems probable that this sac is homologous with the abdominal gland of *Ca. trifascialis*. It is also possible that the organ could be widespread in the thyridid larvae and characteristic to the Thyrididae. This will be examined in future studies. In the field at Lambir, Sarawak on Borneo Island, we have not observed any behavior involving emitting liquid chemicals from the organ against stimulation of the larval body in the new species.

Larval chaetotaxy in this new species is fundamentally the same as in the known species (Hasenfuss, 1980 ; Darling, 2003 ; Yoshiyasu, 2011): prothorax to metathorax with 2 L setae and 2 SV setae, respectively. However, the prolegs on the 3rd to 6th abdominal segments of the larva usually have uniordinal or biordinal crochets arranged in a single circle in the Thyrididae (Hasenfuss, 1980 ; Neunzig, 1987 ; Yoshiyasu, 2011). For example, in *Thyris fenestrella* (Scopoli, 1763), the abdominal prolegs with *ca.* 25 biordinal crochets in a circle (Hasenfuss, 1980), and in *Herdonia margarita* Inoue, 1976, the crochets are uniordinal in a circle (Yoshiyasu, 2011). However, the new species has triordinal crochets in triserial circles (Fig. 7C) and this is the same as that in *Ca. trifascialis* (Darling, 2003). Together with the presence of the inner sac on the 1st abdominal segment, it is suggested that the new species is quite close to the species belonging to *Calindoea*.

The early instar larvae of the new species feed on the leaf surface inside silken nests woven (Figs 8E-F) and they changed to retreat-making behavior from the mid-instar larval stage, with two types of retreat: the first and second leaf rolls (Fig. 9). In previous reports on the larval performance of the Siculodinae, Li (1996) and Darling (2003) did not mention this behavioral change during the larval stage, and reported only their retreat-making behavior. This was likely due to a lack of observation of the egg and early instar larva in their studies. The larva of a siculodine species, *Microbelia canidentalis* (Swinhoe, 1906), showed similar feeding habits to this new species (Yoshiyasu, unpublished observation). The behavior of the first-instar larvae in other siculodine species should be examined in future studies to determine whether the behavioral sequence is common in the Siculodinae.

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摘　要

ボルネオ産マドガ科の 1 新属・新種の記載ならびに新種の幼生期の形態および生態（鱗翅目，マドガ科）（吉安　裕・清水加耶・市岡孝朗）

マレーシアのボルネオ島産のオオバキ属（*Macaranga*）植物 3 種を寄主とするマドガ科の 1 新属の 1 新種を記載し，DNA バーコード情報を登録した．また，その幼生期の形態と生態について初めて記述した．本種は，初め Robinson *et al*.（1994）によって未記載種 *Pharambara* sp. として分類され，近年は Sutton *et al*.（2015）で *Collinsa* sp. 2 として図示されていた．この両属のタイプ種について，翅の翅形と斑紋ならびに♂交尾器の形態を比較・検討した結果，本新種はこの近縁のいずれの属にも属さず，また，これらが属するマダラマドガ亜科 Siculodinae の他属とも形態的に異なることが明らかになったので，本新種に対して，新属 *Shafferiella* Yoshiyasu, n. gen. を創設した．

The genus *Shafferiella* Yoshiyasu, **n. gen.**

頭部にケトセマと単眼を欠く．触角は雌雄とも糸状．ラビアル・パルプスは細く上向する．翅脈は他のマドガ科の属と同様に各脈が基部で融合することはない（Fig. 1D）．翅の斑紋は全体にクリーム色を呈し，前翅の翅頂部付近に特徴的な白色の短い帯をもち，前・後翅の中央には比較的顕著な暗色の横帯がある．♂成虫の第 8 と第 9 腹節間の節間

膜は長く，その一部に 1 対のヘア・ペンシルをもち，交尾器のバルバは細長く，後半部はとくに細まることで，近縁の *Pharambara* 属や *Collinsa* 属から区別できる．♀交尾器では，交尾口は狭い；ドクツス・ブルサエは細長，楕円形のコルプス・ブルサエには小歯をもつシグヌムを有する．これらの形質のうち，前翅の翅頂部付近の短い白帯，♂成虫の第 8 と第 9 腹節間の長い節間膜，および♂交尾器のバルバの状態の共有によって，下記の *Collinsa* 属として扱われていた種 *pallida*（ウスマダラマドガ）と種 *hamifera* を本新属のもとに置いた．

Shafferiella pallida（Butler, 1879）, **新結合**
Shafferiella hamifera（Moore, 1888）, **新結合**

Shafferiella macarangae Yoshiyasu, Shimizu-kaya & Itioka, **n. sp.**（オオバギマダラマドガ：新称和名）

成虫（Figs 1A–C）．前翅長：♂ 7.8–9.4 mm，♀ 8.5–10.8 mm．頭部は淡褐色．ラビラル・パルプスは暗褐色で湾曲して上向し，第 3 節は短く細い．触角は雌雄とも前翅の約 1/2 の長さ；糸状であるが，やや扁平．前脚は短く，中脚は後脚よりも長い．前翅はやや細長く，淡褐色で目立たないが細く短い茶色の横線が全体に分布する；前縁部に 7 個の小白斑をもつ；翅頂付近の亜外縁部の R4 脈と M2 脈間に三日月状の白色条斑をもつ；M2 室には 3–5 個の小黒点が並ぶ．後翅は短く，淡褐色で，多数の弱い網目状の細い線のほか，中央部には明瞭な褐色横線が斜め内方に走る．

♂交尾器（Fig. 2）：テグメンは背面の前方でＶ字型に陥入し，側面からみて背部は波打つ；ウンクスの基部は幅広いが，後方部は幅が狭く側面からみて鎌状を呈しその背側部には多数の小刺毛を具える；グナトスはウンクス基部からテグメン腹面に沿って前方に伸び，腹中線上の針状のコクレアに終わる；バルバは基部を除き細長く，背方に緩く湾曲して後方に長く伸びる；内面基部には小突起のある硬化部をもつ．サックスから前に伸長する弱い硬化部にヘア・ペンシルがあり，バルバ全体を側面から覆うように後方に伸びる．

♀交尾器（Fig. 3）：交尾口は狭く，その腹面にはやや硬化した逆三角形の突起が形成される；アントルムは小さく発達；ドクツス・ブルサエは細長く，コルプス・ブルサエは長楕円形で小さなシグヌムをもつ；第 8 腹節の背板は短く，アポフィシス・アンテリオリスは第 7 腹節背板の約 1/3 の長さ；アポフィシス・ポステリオリスはアンテリオリスよりやや長い；パピラ・アナリスは丸く側部に多数の刺毛をもつ．

卵（Figs 5A–E）．長さ 0.52 mm, 直径 0.25 mm．やや長い俵状で，精孔部のある上面はやや細く，産下面の下面は扁平．側部には 13 または 14 本の規則的な縦の稜線をもち，それらの間には多数の等間隔の横線が平行して走る．

終齢幼虫（Figs 4–5）．体長 15–18 mm，頭幅 1.6–1.7 mm．円筒形．頭部は一様に淡橙色で P1 と A3 刺毛を除きその他の刺毛は短い．6 個の個眼は比較的小さく離れて分布．マンディブルは茶色，ほぼ四角形で 4 歯を有する．前胸背盾は淡黄褐色で，後方部が隆起する；背盾下の気門は大きく円形．中胸と後胸は短く，後胸では中胸に比べ D, SD, L 刺毛群はより前方に位置し，短い．胸部 3 節の L 刺毛群と SV 刺毛群はそれぞれ 2 本．胴部は半透明の淡い黄褐色；刺毛は発達し，特に背方の刺毛は長い．第 1 腹節の SD1 刺毛は短く，気門の斜め後方にある；L1 と L2 の刺毛基板と L3 の刺毛基板の間で気門の腹方には内側に嚢状器官をもつ．第 1–8 腹節の SD2 刺毛は痕跡的．第 9 腹節では D1 と D2 刺毛は同一基板上にあり，反対側の同刺毛基板と背中線で合一する；L 刺毛は 1 本．第 1–9 腹節の SV 刺毛は，それぞれ，2，3，3，3，3，3，2，1，1 本．第 3–6 腹節の腹脚の鉤爪は約 50 本からなり，不規則な三様の円環状配列．第 10 腹節の腹脚には半環状配列の不規則な三様の約 20 本の鉤爪をもつ．

蛹（Fig. 6）．体長 8.5–10.5 mm, 横幅 2.5–2.8 mm．体形は太く短いが，他の種に比べてやや細く，茶褐色．触角は前翅の約 4/5 の長さ，中脚はほぼ前翅端に達する．後脚は口吻先端の後方に短く現れる．

生態（Figs 8–9）．卵は寄主の葉の裏面に，個々の卵が一定の間隔をおいた集団で産下される．1 集団における卵数は平均 83.3 個であった．孵化幼虫は葉脈沿いに天幕状の絹糸を紡ぎその中にいて，葉の表皮を摂食する．中齢期になると葉縁に移動し，そこで葉を直線状に裁断し，中肋に向かって葉を巻いて巣（第一の巣）をつくり，巣内部の葉を摂食する．齢が進むと最初の巣を遺棄し，上の方の新しい葉に移動し再度葉縁から葉脈とほぼ直角となるように裁断し，その部分から内方に葉を巻いて円筒形とそれを覆う円垂形部分からなる新たな巣（第二の巣）をつくる．終齢幼虫は第二の巣の円筒形部分の片方を絹糸で固くとめて中で蛹になる．本マドガの寄主となるオオバキ属の 3 種はすべてアリとの共生関係をもついわゆるアリ植物であるが，野外ではマドガ幼虫が寄生していた植物には寄生されていなかった植物と比べてアリ類の随伴は少なく，マドガ幼虫とアリ類との遭遇も観察されなかった．

寄主植物．*Macaranga bancana*（Miq.）Müll. Arg., *M. trachyphylla* Airy Shaw, *M. umbrosa* S. J. Davies（トウダイグサ科）．

分布．マレーシア（Sarawak, Sabah, Kalimantan Tengah, W. Malaysia）, シンガポール．平地から標高 1,200 m までの低高地．

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